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ORIGINAL ARTICLE

Optimizing Postoperative Radiation Therapy in Ewing's Sarcoma with Lung Metastasis: A Case of Whole Lung Bath Irradiation

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ABSTRACT

Introduction: Ewing's sarcoma (ES) is a rare but highly aggressive malignancy, predominantly affecting children and young adults, with a characteristic presentation of bone or soft tissue involvement. Whole lung irradiation (WLI) is used in the treatment of pulmonary metastases, especially following chemotherapy and surgical resection of the primary tumor. The purpose of this study was to assess the effectiveness of whole-lung irradiation in a young adult patient with metastatic Ewing's sarcoma.

Patient Information & Systemic Therapy: A young adult with progressively worsening tibial pain and swelling was diagnosed with Ewing's sarcoma after imaging and biopsy confirmed the presence of the tumor. Neoadjuvant chemotherapy (VAC/IE) was administered, followed by surgical resection of the femoral tumor. Interim imaging showed significant reduction in pulmonary metastases, prompting the decision to proceed with whole lung irradiation.

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Material and Methods: The patient underwent whole-lung irradiation using a high-precision radiation therapy technique. A thermoplastic mask was employed for immobilization during CT scanning and radiation treatment. The radiation planning utilized Varian Somavision for tumor volume delineation, and the treatment plan was created using IMRT (Intensity-Modulated Radiation Therapy) with a Halcyon Elite 4.0 machine. The patient was treated with 18 Gy in 12 fractions. The breath-hold technique was utilized to minimize respiratory motion during radiation delivery. Cone Beam CT (CBCT) and portal dosimetry were employed to verify treatment accuracy.

Results: The radiation dose was successfully delivered to the target volume (PTV), with a high degree of precision, as evidenced by dosimetric parameters. The V95% was above 95%, indicating that 95% of the target volume received the prescribed dose. The homogeneity index (P-HI) and conformity index (CI) showed favorable dose distribution, ensuring the target volume received a uniform dose while sparing surrounding healthy tissues. Critical organs such as the heart, esophagus, and liver received doses within safe limits, and no significant adverse effects were observed.

Conclusion: Whole-lung irradiation using IMRT and advanced techniques like the breath-hold method and cone beam CT verification represents a promising strategy for managing pulmonary metastases in Ewing's sarcoma. This individualized treatment plan maximized the therapeutic dose to metastatic lesions while minimizing risks to healthy organs, highlighting the potential for optimizing radiation therapy in this patient population.

KEYWORDS:

• Surgical • Volume • Significant • Chemotherapy

INTRODUCTION

Ewing's sarcoma (ES) is a rare but highly aggressive malignancy, often affecting bones or soft tissues in children and young adults. Ewing sarcoma (ES) was first reported by James Ewing in 1921, as a primary, separate, malignant tumor with no osteogenic properties. Whole lung irradiation (WLI) may be part of the treatment plan, especially when there is concern about micrometastatic disease or after surgical resection.[1] ES is now considered a highly malignant sarcoma of bone or soft tissue and belongs to the group of small round blue cell neoplasms of neuroectodermal origin[2] ES is the second after osteosarcoma most common type of primary bone malignancy in children and young adults. Event-free survival (EFS) rates raised to greater than 70% for localized disease.[3,4]

Patient Information & Systemic Therapy

A young adult presented with several months of progressively worsening anterior tibial pain and swelling. MRI demonstrated a destructive diaphyseal lesion with cortical breach and an associated soft-tissue extension. PET-CT revealed intense FDG uptake at the primary site and multiple bilateral pulmonary nodules measuring 4–9 mm. No extrapulmonary metastatic sites were detected. Histopathology of a core biopsy confirmed Ewing sarcoma. Neoadjuvant chemotherapy consisted of standard VAC/IE administered over five cycles. This regimen was selected based on cooperative group protocols demonstrating improved survival with dose-intensified systemic therapy.[5] Treatment was well tolerated. Interim PET-CT showed near-complete resolution of pulmonary metastases, with only a single subcentimeter nodule without FDG avidity. MRI showed substantial regression of intramedullary tumor volume without joint, neurovascular, or skip involvement.

MATERIAL AND METHODS

The Ewings sarcoma patient received **whole lung irradiation** for the metastatic lesions, following the successful surgical resection of the primary femoral tumor and completion of chemotherapy. The treatment plan was designed with the goal of maximizing tumor control in the lungs while sparing surrounding healthy tissue.

Mould and CT

Thermoplastic masks are commonly used in radiation therapy to ensure that the patient remains in the exact same position for each treatment session. The mask is created by heating a thermoplastic material in hot water, which is then molded to fit the patient's body .This helps of AIO (All IN One) Corban Fiber base plate with immobilize the patient during both CT scanning and treatment, ensuring that the radiation is delivered with high precision to the tumor. The **Philips invasive CT scanner** is used to obtain detailed cross-sectional images of the lung and surrounding structures. A **slice thickness of 3mm** is standard for creating high-resolution images that help accurately delineate the tumor. The CT scan is usually done during **both inspiration and expiration** phases of the patient are breathing cycle. **Inspiration** imaging helps define the tumor and surrounding lung tissue when the lungs are fully inflated, which is important for planning radiation to a moving target. **Expiration** imaging shows the position of the tumor and organs when the lungs are contracted, providing a clearer view of structures within the chest when movement is minimal.

Varian **Somavision** is advanced **contouring software** to delineate **tumor volume (GTV)**, **clinical target volume (CTV)**, and **planning target volume (PTV)** based on the CT images. **GTV**-Gross tumor volume (visible tumor tissue). **CTV:** Entire bilateral lung parenchyma from apices to diaphragmatic insertions. **PTV:** ITV expanded by 0.5–0.8 cm according to institutional motion and setup data Table 1. **OARs:** Heart (with substructures), esophagus, spinal cord, liver, thyroid, and breast tissue (if applicable), delineated following pediatric/ AYA sarcoma guidelines.[6]

Table 1: Whole-Lung Irradiation (WLI) Simulation and Planning Parameters

Planning Component	Details
Patient Position	Supine, arms elevated
Simulation	CT **Inspiration and Expiration**
Lung Motion (ITV Basis)	0.4-0.7 cm excursion
CTV	Entire bilateral lung parenchyma
PTV Margin	0.5-0.8 cm, motion-adjusted
Treatment Technique	IMRT using TWO Isocenter
Beam Energy	6FFF
Algorithm	AAA (**Anisotropic Analytical Algorithm**)
Daily Verification	CBCT

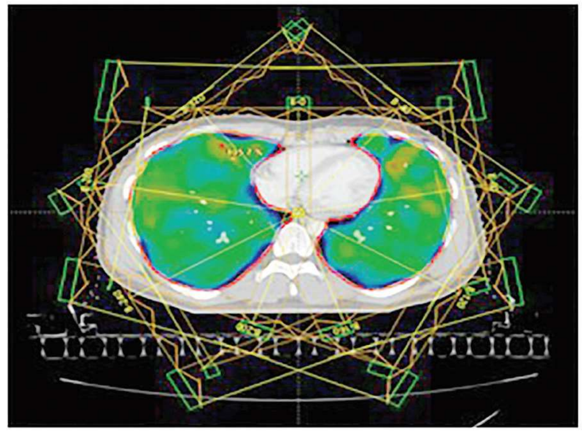

Figure 1: 95% Dose Color Wash of Whole Lung Irradiation

Varian Eclipse 17.0 AAA (Anisotropic Analytical Algorithm) was likely used for **dose calculation**, which is a high-precision method for modeling how radiation interacts with tissues. The plan is created to deliver the prescribed dose to the **PTV** while minimizing the dose to surrounding **critical structures (OARs)** such as the heart, spinal cord, liver.

2.2 Radiation Treatment planning:

Treatment Machine: **Halcyon Elite 4.0** with **FFF beam** (flattening filter-free beam) & **Varian Eclipse 17.0 AAA (Anisotropic Analytical Algorithm)**

- **Modality**: Intensity-Modulated Radiation Therapy (IMRT)
- **Dose Rate**: 800 MU (Monitor Units) per minute
- **Treatment Setup**: The patient was positioned in a **head-first, supine** position, with **manual breath-hold technique** used to minimize motion-related uncertainties during radiation delivery. The patient was instructed to hold their breath during irradiation, reducing the risk of motion artifacts, particularly in the lungs.
- **Treatment Time**: Approximately 15 minutes per session.

Isocenter Setup:

- **Isocenter A**:
  - Gantry Angles: **160°, 120°, 80°, 40°, 0°, 320°, 28°, 240°, 200°**
  - Collimator Angles: **0° and 90°**
- **Isocenter B**:
  - Gantry Angles: **160°, 120°, 80°, 40°, 0°, 320°, 28°, 240°, 200°**
  - Collimator Angles: **0° and 90°**

The gantry angles and collimator angles of Isocenter A and Isocenter B ensuring comprehensive coverage of the lung metastases. Distance of both isocenters is 10.5cm. The use of multiple gantry angles allows for **optimal dose distribution** while minimizing radiation exposure to critical structures. The patient received **18 Gy in 12 fractions**, with each fraction delivering **1.5 Gy per session**. This dose was delivered to the entire lung to target the metastatic lesions. The treatment was designed to ensure that the **dose to OARs** remained within safe limits as per established protocols. This was achieved by modulating the intensity of the beams and optimizing the **beam angles** and **dose distribution**.

CBCT (Cone Beam CT) is used during the treatment sessions to verify that the patient is in the correct position and that the tumor is aligned with the planned target. This imaging is done at the start of each fraction (or treatment session) and helps confirm that the **treatment position is accurate** by comparing the current CBCT images with the original planning CT figure 2.

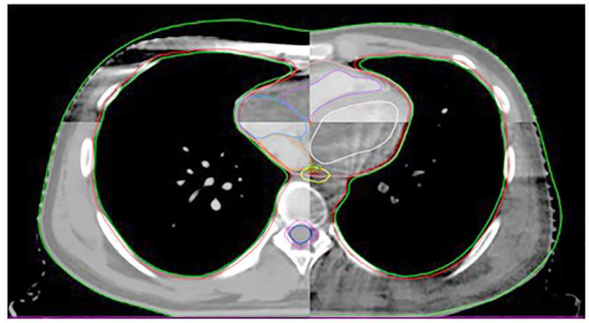

Figure 2: Daily CBCT reconstruction Image

Portal dosimetry Figure 3 is used to measure the dose distribution in real-time during treatment. It verifies whether the delivered dose matches the planned dose. The **3mm/5% criteria** indicate that the QA system checks if the dose delivered is within 3mm of the planned position and 5% of the planned dose. This helps ensure that radiation is being delivered accurately and safely. QA procedures are typically performed at the start of treatment course to confirm that the treatment delivery system is functioning correctly.

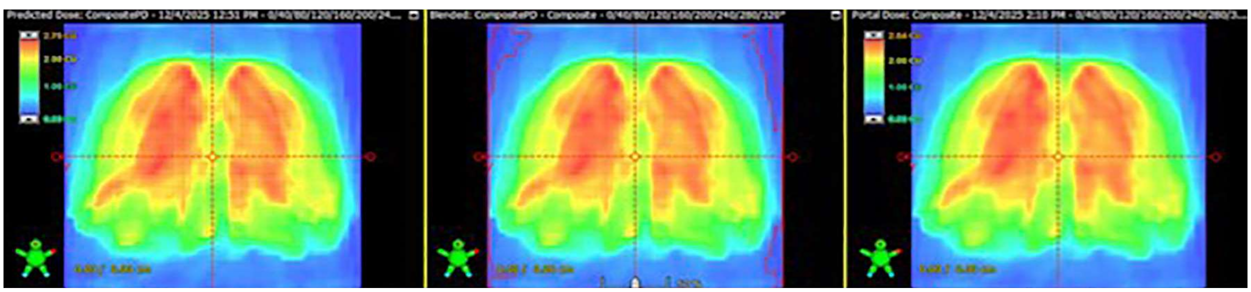

Figure 3: Portal Dosimetry QA Verification

Breath-Hold Technique:

The **manual breath-hold technique** was utilized to reduce motion artifacts, particularly in the lungs, ensuring precise targeting of the metastatic nodules. This technique involves the patient holding their breath during irradiation, stabilizing lung position and reducing the risk of mistargeting due to respiration-related lung motion.

RESULT

The **PTV** shows a fairly good dose distribution with **V95%** being above 95% of the prescribed dose (ideal for treatment efficacy). **Conformity Index (CI)** is relatively high at 0.92, suggesting that the radiation is conforming well to the target volume. The **Homogeneity Index (P-HI)** is quite low (0.11), Table 2 which generally indicates a more uniform dose distribution across the target volume, meaning there aren't extreme variations between high and low doses and moreover integral dose is less in IMRT plan.

Table 2: Whole-Lung Irradiation PTV Dosimetric Parameters

PTV Parameters	Values
PTV Volume	5006.1cc
$D_{2\%}$	18.84 Gy
$D_{98\%}$	16.82 Gy
$D_{50\%}$	18.23 Gy
D_{max}	18.15 Gy
Dmin	12.65 Gy
P_{IV}	5077.93 cm^3
$V_{95\%}$	48.32.62cc

table cont.....

CI	0.92
HI	0.11

OAR Dosimetric values Table 3 displays Spine receives a lower dose than the prescribed dose, with the maximum dose below 18 Gy, which is beneficial for sparing this critical structure. The liver receives a much lower dose, indicating good sparing and minimal radiation exposure. The dose to the esophagus is controlled but relatively close to the prescribed dose, potentially needing monitoring for long-term effects The heart receives a modest dose, with **V10 Gy** = 62.8% and **V15 Gy** = 16.6%. This suggests that a significant portion of the heart volume is exposed to lower doses, but there is still a risk of toxicity in the long term. The lung region (A-Pulmonary) receives a high dose, with **V10 Gy** = 99.7% and **V15 Gy** = 39.6%. This high-volume exposure could potentially cause radiation-induced complications, such as fibrosis, especially in the long term. The aorta receives a dose of 13.35 Gy, with **V10 Gy** = 82.7% and **V15 Gy** = 30.6%. While this is within acceptable limits, it's important to monitor for any vascular-related complications. The left atrium receives a relatively low dose (D mean), with **V10 Gy** = 60.6% and **V15 Gy** = 7.5%, which is favorable for sparing this structure. The right atrium's dose (Dmean) is higher, with significant exposure (87.3% of the volume receiving ≥10 Gy). This may require monitoring for potential cardiac effects. The left ventricle receives a lower dose (Dmean), with **V10 Gy** = 37.7% and **V15 Gy** = 1.3%, which indicates good sparing. The right ventricle also receives a relatively lower dose, with **V10 Gy** = 44% and **V15 Gy** = 3.4%, suggesting minimal risk to this structure in DVH. Figure.[4]

Table 3: OAR Dosimetric values

OAR Structure	Dose	
Spine	D_{Max}	13.45 Gy
Liver	D_{MEAN}	6.84 Gy
Esophagus	D_{MEAN}	12.74 Gy
Heart	D_{MEAN}	11.4 Gy
	$V_{10\,Gy}$	62.8%
	$V_{15\,Gy}$	16.6%
A-pulmonary	D_{MEAN}	18.27 Gy
	$V_{10\,Gy}$	99.7%
	$V_{15\,Gy}$	39.6%
Aorta	D_{MEAN}	13.35 Gy
	$V_{10\,Gy}$	82.7%
	$V_{15\,Gy}$	30.6%
Atrium left	D_{MEAN}	11.01 Gy
	$V_{10\,Gy}$	60.6%
	$V_{15\,Gy}$	7.5%
Atrium right	D_{MEAN}	13.55 Gy
	$V_{10\,Gy}$	87.3%
	$V_{15\,Gy}$	35.2%
Ventricle left	D_{MEAN}	9.5 Gy
	$V_{10\,Gy}$	37.7%
	$V_{15\,Gy}$	1.3%
Ventricle right	D_{MEAN}	9.91 Gy
	$V_{10\,Gy}$	44%
	$V_{15\,Gy}$	3.4%

table cont.....

DISCUSSION

Since the 1970s, WLI has been a component of this aggressive therapy[9] although clear data supporting the necessity of its use, particularly for adults, are lacking. In the pediatric literature, there is substantial evidence to support WLI among ES patients with localized disease.[7] This **IMRT-based radiation therapy plan** for whole lung irradiation is tailored to the patient's specific anatomy and tumor distribution. The use of **Halcyon Elite 4.0** with **FFF beam** ensures a rapid dose delivery with high precision, critical for sparing normal lung tissue while effectively irradiating the metastatic lesions. The inclusion of **multiple gantry angles** (ranging from 0° to 320°) allows for a more **conformal dose distribution**, which minimizes the dose to healthy tissue. The **manual breath-hold technique** adds an additional layer of precision, reducing the impact of respiratory motion on the treatment accuracy. By stabilizing the lung during treatment, this technique helps ensure that radiation is delivered to the tumor with minimal risk to surrounding normal tissue. With the use of advanced **dose modulation** and **beam shaping**, the plan ensures that **dose constraints for OARs** (such as the heart and esophagus) are adhered to, in line with standard radiation oncology guidelines. This is critical to minimize the long-term risks of radiation-induced damage to these sensitive structures. Potential cardiac toxicity from WLI must be acknowledged, along with consideration of research and efforts to minimize cardiac dose such as the cardiac-sparing IMRT technique for WLI.[8] The **Halcyon Elite 4.0** system, with its **FFF beam** and **800 MU Dose rate**, enables efficient treatment delivery in approximately **15 minutes per session**, improving patient comfort while maintaining high precision in dose delivery.

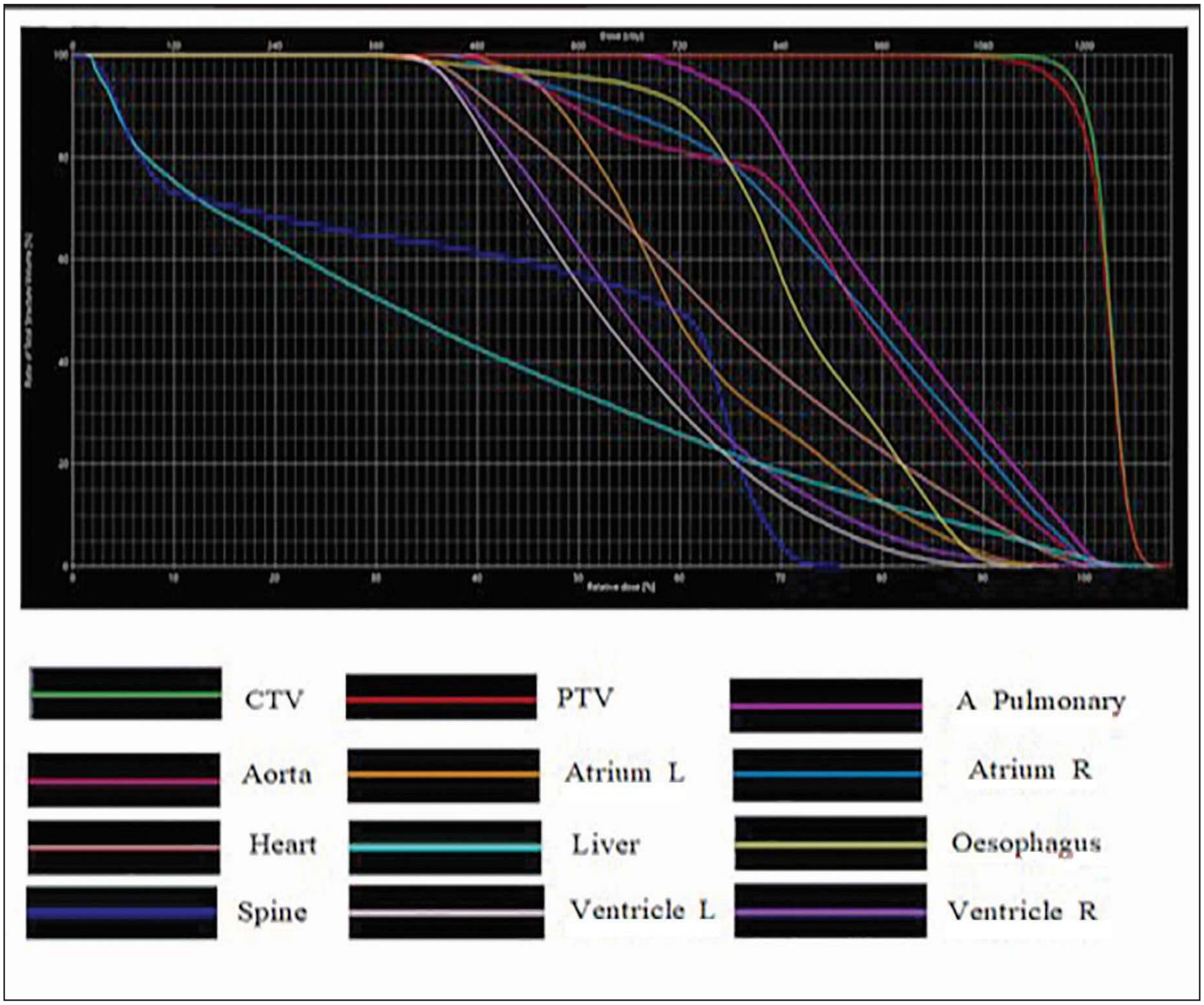

Figure 4: Dose Volume Histogram of Whole Lung Irradiation

CONCLUSION

This study highlights the importance of individualized treatment strategies in pediatric patients with ES and pulmonary metastases. The combination of **IMRT**, **breath-hold techniques**, and advanced planning using the **Halcyon Elite 4.0** radiation system allowed for effective treatment of **lung metastasis** in this patient with **Ewing's sarcoma**, while minimizing the risks to critical organs. The **dose constraints for OARs** were met, and the patient tolerated the treatment well with no significant adverse effects. This treatment approach, combining **careful dose planning**, **advanced imaging**, and **personalized techniques**, exemplifies the potential for optimizing radiation therapy in cases of metastatic disease.

Conflict of Interest statement: No conflicts of interest to declare.

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